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Letter to the Editor

Techno-economic analysis and environmental impact of fuel economy labels for passenger cars in Indonesia

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ABSTRACT

In Indonesia, the transportation sector is the third largest energy consuming sector (28%) after the industrial and residential sector. Transport energy consumption is mostly driven by the road sub-sector. In order to reduce fuel consumption and emissions production in the transportation sector, fuel economy labels for passenger cars have been introduced globally. Labelling could play an important role in consumers' vehicle purchasing decisions between similar vehicles that have different fuel efficiency ratings. Currently, Indonesia does not have fuel economy labels. However, it is expected that fuel economy labels will be implemented in the near future due to the growth of passenger cars and the increasing demand for oil. This study is to calculate potential techno economic analysis and emissions reduction when implementing fuel economy labels for passenger cars in Indonesia. It has been found that fuel economy labels will save a significant amount of fuel, economical benefits and emissions reduction in this country.

1. Introduction

In Indonesia, the transportation sector is currently the third largest energy consuming sector (28%) after the industrial sector (40%) and residential sector (29%). Despite the economic slowdown during the Asian financial crisis in 1997, transportation energy consumption of Indonesia grew at a robust rate of 6.3% per year over the past two decades as shown in Fig. 1.Transport energy consumption was mostly driven by the road sub-sector and accounted for about 87% of the incremental growth. Fig. 2 shows percentage of road sector consumption of total energy consumption in Indonesia. It is expected that the continued economic growth and development of a vehicle manufacturing industry will result in a substantial increase in the number of passenger vehicles from 3.4 million units in 2002 to 13.9 million units in 2030 [1].

Since Kyoto protocol has set policies to reduce CO_2 emissions in all sectors including transport and within that the automotive industry [4], Indonesian government began implementation of some measures to prevent air and noise pollution for new vehicles. Government regulations mandate that new vehicles sold in Indonesia must comply with the Euro 2 standard starting from January 2005. However, this regulation became effective in January 2007 with the phase out of leaded gasoline [5].

There are many approaches to improve vehicle fuel economy. Fuel economy label is one of the most effective approaches [6]. A fuel economy label is a mandatory or voluntary sticker that is affixed to vehicles containing information on the energy efficiency or energy consumption of the vehicles. Samples of fuel economy labels are presented in Fig. 3 [10,11,21]. Thus, fuel economy label allows consumers to select the most efficient vehicle between similar vehicles that have different fuel efficiency ratings. The effectiveness of label is highly dependent on how it presents information to the consumer. Energy labels will work effectively when a variety of model efficiencies exist on the market [7]. Generally, there are three kinds of labels [8,18,19,23]:

- Endorsement labels,
- single-attribute certification programs,
- comparative labels, and
- information-only labels.

Endorsement labels are essentially "seals of approval" given according to specified criteria. Single-attribute certification programs certify that claims made for a single-attribute of a product meet a specified definition. Comparative labels allow consumers to compare performance among similar products using either discrete categories of performance or a continuous scale. Information-only labels simply provide data on a product's performance [8]. The labels are not only to set a guideline of efficiency that manufacturer should follow; they but also encourage the manufacturers to improve their product [9].

1.1. Requirement of car labels

A label for new passenger cars, aimed to inform consumers about the fuel economy of different passenger cars, should be [13]:

(i) Simple and easily understood by purchasers.
(ii) Insensitive for manipulation: it should not be possible to change the classification of a model by simple manipulation by the manufacturer.
(iii) Durable in order to make sure that current as well as future cars are classified correctly.
(iv) Workable: standardized fuel consumption data have to be based on available vehicle characteristics such as mass, external dimensions, specific engine power or specific carrying capacity.

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Nomenclature

AS_i^P	applicable stock of passenger cars in year i
AS_{i-1}^P	applicable stock of passenger cars in year $i-1$
ANS_i^P	annualized net savings in year i for passenger cars (IDR)
BFC_s^P	baseline fuel consumption in the year of fuel economy standards enacted for passenger cars (L/year)
BS_s^P	bill savings in year i for passenger cars (IDR)
CRF	capital recovery factor
d	interest rate per year (%)
Em_k	emissions k for fuel type a unit litre (kg/L)
ER_i^P	emission reduction in year i of passenger cars (kg)
i	the particular year
IIC_s^P	initial incremental cost of passenger car (IDR)
L^P	lifespan of passenger car
NS_i^P	net savings in year i for passenger cars (IDR)
Nv_i^P	number of passenger cars in year i
Nv_{i-1}^P	number of passenger cars in year $i-1$
PF_i^P	fuel price in year i (IDR/L)
$PV(ANS_i^P)$	present value of net money savings in year i for passenger cars (IDR)
SFC_s^P	standards fuel consumption of passenger cars (L/year)
Sh_i^P	shipments of passenger cars in year i
SSF_i^P	shipment survival factor in year i for passenger cars (%)
T	target year
TFS_i^P	total fuel savings by the total stock of passenger cars in year i (L/year)
UFS_i^P	initial unit fuel savings of a passenger cars car in year i (L/year)
Ydb	year of discount rate base
Yse_s^P	year of standards enacted of passenger cars
Ysh_i^P	year i of shipment of passenger cars

Superscripts

P	passenger cars
K	number of emission

Subscripts

I	in the year i
S	year of standards enacted

(v) Conspicuous and well known in order to achieve purchaser's attention.
(vi) Adjustable to technological developments in fuel economy.
(vii) Accepted and supported by consumers, authorities, automobile and consumer associations and if feasible, by the car industry and car dealers. The impacts of introducing fuel economy labels usually are energy, economical and environmental. This paper attempts to calculate potential economical and environmental benefit of implementing this program in Indonesia. The economical impacts of the labels are the potential bill savings, net savings and cumulative present value, which are a function of the fuel consumption and fuel price.

2. Survey data

Like any other developing country, it is difficult to collect complete statistical and technical data in Indonesia because of government planning lack. In fact, the necessary data for this study are the number of passenger cars and relative fuel efficiency data of passenger cars. To make a range of passenger cars class, the relative fuel efficiency grades of passenger car are divided into five levels (1–5) [6,21,22]. The statistical data and relative efficiency grades of passenger cars are tabulated in Tables 1 and 2 [6,12].

The impact of fuel economy labels consists of potential fuel savings, economical and environmental impacts. Typically, the impact of fuel economy labels is obtained over a longer period

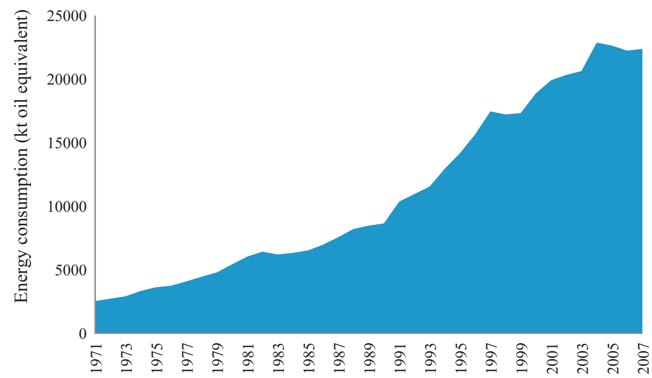

Fig. 1. Road sector energy consumption (kt of oil equivalent) in Indonesia between 1971 and 2007 [2].

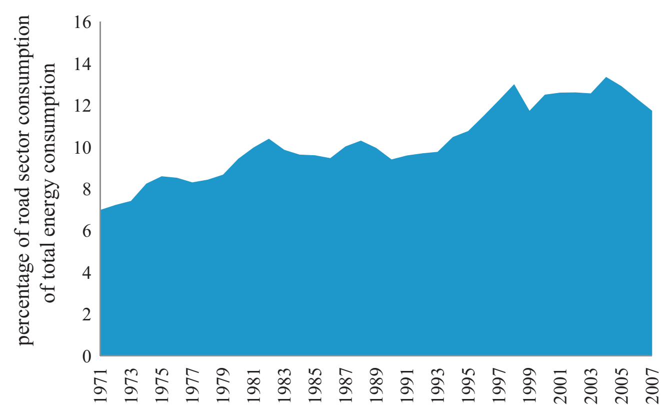

Fig. 2. Road sector energy consumption (% of total energy consumption) in Indonesia [3].

Table 1
Statistical data of passenger cars in Indonesia [12].

Year	Passenger car
1987	1,170,103
1988	1,073,106
1989	1,182,253
1990	1,313,210
1991	1,494,607
1992	1,590,750
1993	1,700,454
1994	1,890,340
1995	2,107,299
1996	2,409,088
1997	2,639,523
1998	2,769,375
1999	2,897,803
2000	3,038,913
2001	3,261,807
2002	3,403,433
2003	3,885,228
2004	4,464,281
2005	5,494,034
2006	6,615,104
2007	8,864,961
2008	9,859,926

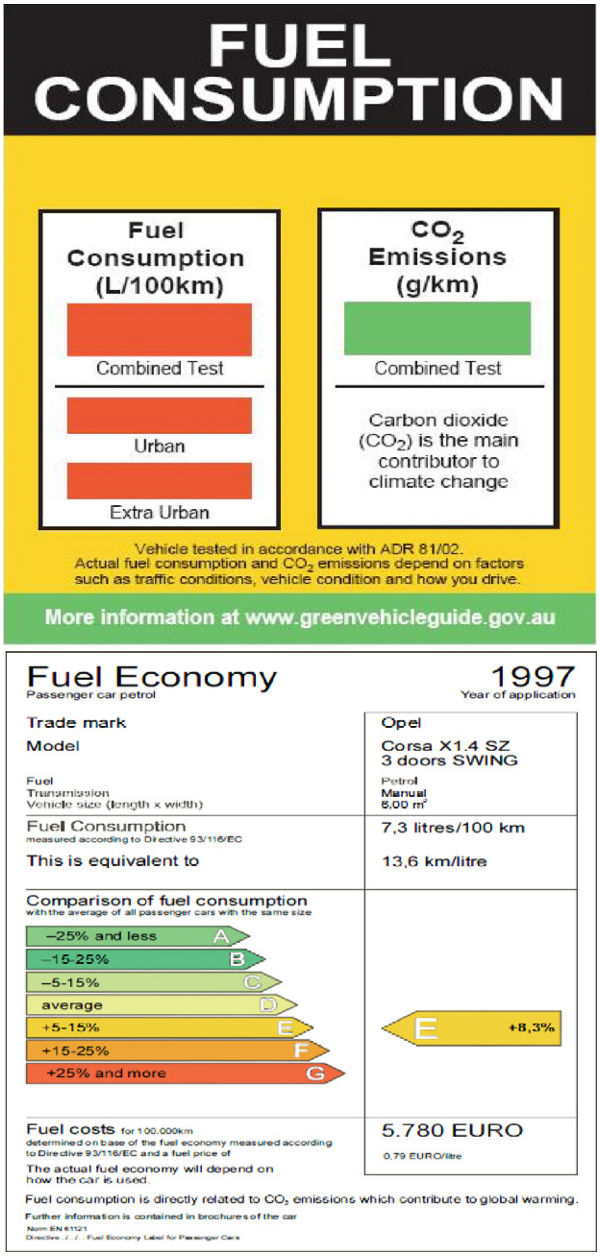

Fig. 3. Samples of fuel economy label in Australia and the European Union [10,11].

than the standard. However, this study only examined the impact of fuel economy labels for the effective period of the standards. To get the results, some input data are necessary, which have been collected from different sources/references such as automobile manufacturers, fuel refuelling stations, and country reports. The input data for petrol and diesel passenger cars are presented in Table 3 [6].

Table 2
Relative fuel efficiency grades of passenger car [6].

Fuel consumption (FC)	Central value (FC) km/L	FC grade
0.15FC + 13	13	A
0.15FC + 12	12	B
0.15FC + 11	11	C
0.25FC + 10	10	D
0.5FC + 9	9	E

Table 3
Input data for potential fuel saving due to the labels [6,15].

Descriptions	Values
Year labels enacted	2015
Discount rate	7%
Initial incremental cost	IDR 2,001,714
Life span	10 year
Current average fuel price	IDR 6000/L
Standards fuel consumption	1210 L/year
Labels fuel consumption	1100 L/year
CO_2 emission	2.415 kg/L
HC emission	53.98 g/L
NO_x emission	44.76 g/L
CO emission	114.5 g/L
Percentage of petroleum emissions in Indonesia	1.9%

1 USD = 9800 IDR.

3. Methodology

3.1. Method of predicting data

This analysis is generally based on modelling methodologies to figure out the potential fuel saving and emissions from passenger cars in Indonesia in the future. Some of the data are already available but other data have to be calculated with respect to the number of passenger cars in Indonesia. The method used to estimate this number is polynomial curve fitting. The method is an attempt to describe the relationship between variable X as a function of available data and a response Y, which seeks to find some smooth curve that best fits the data, but does not necessarily pass through any data points. Mathematically, a polynomial of order k in X is expressed in the following form [14,16,24]:

$$Y = C_0 + C_1X + C_2X^2 + \cdots + C_kX^k \tag{1}$$

3.2. Shipment

Shipment is the difference between the numbers of passenger cars in predicting years minus the number in previous year plus the number of retired passenger cars in the current year. In mathematical form this can be expressed by the equation [7,14,20]:

$$Sh_i^P = (Nv_i^P - Nv_{i-1}^P) + Nv_{i-1}^P \tag{2}$$

3.3. Shipment survival factor

The shipment survival factor is a function of the annual retirement rate and the retirement function. If the standards setting is shorter than 2/3 of the average lifespan of product, shipment survival factor will be 100%. Shipment survival factor for passenger car can be calculated using the following equation [7,14,20,24]:

$$SSF_i^P = 1 - \left[\frac{(Tsh_i^P - Yse_i^P)2/3L^P}{2/3 \times L^P} \right] \tag{3}$$

3.4. Applicable stock

The applicable stock is the stock of the passenger cars in a particular year and the number of cars affected by the fuel economy standards in previous year. The equation is as follows [7,14,20,24]:

$$AS_i^P - (Sh_i^P \times SSF_i^P + AS_{i-1}^P) \tag{4}$$

3.5. Unit fuel savings

The initial fuel savings is the difference between baseline fuel consumption and standard fuel consumption of passenger car. The

initial unit fuel savings is calculated using the equation below [6,7,14,17,24]:

$$UFS_S^P = BFC_S^P - SFC_S^P \tag{5}$$

3.6. Total fuel savings

Total fuel savings in a particularly year is the multiplication of the applicable stock of the passenger cars and the unit fuel savings in the particularly year. The total fuel savings can be expressed mathematically as follow [7,14,24]:

$$TFS_i^P = \sum_{i=S}^{T} AS_i^P \times UFS_i^P \times SF_i^P \tag{6}$$

3.7. Bill savings

The bill saving is a function of the total fuel savings multiplied by the average fuel price. This is can be expressed by the following equation [7,14,22]:

$$BS_S^P = TFS_i^P \times PF_i^P \tag{7}$$

3.8. Capital recovery factor

Capital recovery factor is the correlation between discount rate and lifetime of the passenger car. This correlation expressed by the following mathematical equation [7,14,22]:

$$CRF = \frac{d}{(1-(1+d)^{-L})} \tag{8}$$

3.9. Net savings

There are two ways to determine economical impact e.g., annualized costs and cash flow. In the first method, the incremental cost is spread over the lifetime of the car so that the pattern of expenditures matches the flow of bill savings. This method smoothen the net savings over time and calculated using the following equation [7,14,22]:

$$ANS_i^P = TFS_i^P \times PF_i - \sum_{i=s}^{T} AS_i^P \times CRF \times IIC_S^P \tag{9}$$

The second method is the cash flow over the lifetime of the investment, which assumed that the passenger car is paid for in full when it is purchased. Purchaser incurs the incremental technology cost when the car is purchased, but benefits of higher energy efficiency are spread over life time of the car. This is calculated by the following equation [7,14]:

$$NS_i^P = TFS_i^P \times PF_i^P - Sh_i^P \times IIC_S^P \tag{10}$$

3.10. Cumulative present value

The cumulative present value is a function of annual cost savings and the percentage of real discount rate. The cumulative present value of annualized net savings can be calculated by the following equations [7,14,22]:

$$PV(ANS_i^P) = \sum_{i=SC}^{T} \frac{ANS_i^P}{(1+d)^{(i-Ydb)}} \tag{11}$$

3.11. Emissions reduction by labels

The environmental impact of the labels is the potential emission reduction. The common emissions from fossil fuel passenger cars

Table 4
Prediction of passenger cars numbers in Indonesia.

Year	Number of passenger cars
2015	14,835,331
2016	16,057,422
2017	17,332,115
2018	18,659,410
2019	20,039,308
2020	21,471,807
2021	22,956,909
2022	24,494,614
2023	26,084,920
2024	27,727,828

consist of CO_2, HC, NO_x and CO. The emissions reduction is a function of energy savings. The environmental impact can be calculated by the following equation [7,14,22,24]:

$$ER_i^P = TFS_i^P \times (Em_1 + Em_2 + Em_3 + \cdots + Em_k) \tag{12}$$

4. Results and discussion

4.1. Data analysis

As have been stated in the previous section, polynomial curve fitting is a suitable approach to predict future data. Using Eq. (1) and based on the data shown in Table 1, the total number of passenger cars between 2015 and 2023 can be predicted by the following equation:

$$\text{The total number of passenger cars} = 26,301.10x^2 - 277,071.73x + 1,973,276.59R^2 = 0.93 \tag{12}$$

The result of the predicted number of passenger cars in Indonesia from 2015 to 2024 using the above polynomials equation is shown in Table 4.

4.2. Fuel saving

The energy impact of labels is the potential energy savings of implementing fuel efficiency labels for the passenger cars. The scaling factor is not applicable. This is because the standard (fuel consumptions of the standards) as a baseline of the labels is static.

Using Eqs. (2)–(8), input data in Tables 3 and 4, the results of fuel saving between 2015 and 2024 are presented in Table 5 and Fig. 4 respectively. It can be observed that fuel saving increases gradually from 2014 to 2024 and the total fuel saving during this period is 55,894 million litres.

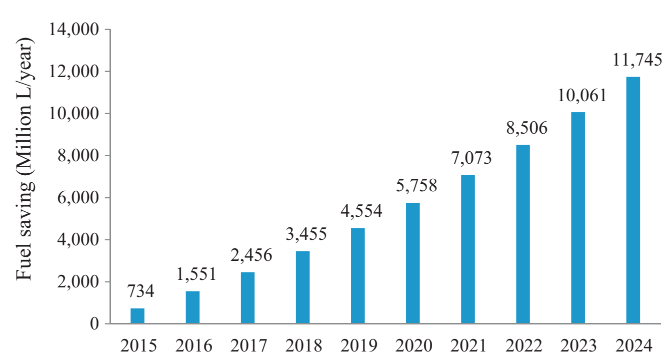

Fig. 4. Annualized fuel saving (million L/year) due to the passenger cars fuel economy labels.

Table 5
Result of the fuel saving and economical impact of fuel economy labels.

Year	Sh	AS	UFS (L/year)	FS (million L/year)	BS (billion IDR)	ANS (billion IDR)	NS (billion IDR)	PV (ANS) (billion IDR)
2015	6,677,031	6,677,031	110	734	4407	2504	−8959	2504
2016	7,425,702	14,102,732	110	1551	9308	5289	−5556	4943
2017	8,226,975	22,329,708	110	2456	14,738	8374	−1730	7314
2018	9,080,851	31,410,558	110	3455	20,731	11,779	2554	9615
2019	9,987,329	41,397,887	110	4554	27,323	15,524	7331	11,843
2020	10,946,408	52,344,295	110	5758	34,547	19,629	12,636	13,995
2021	11,958,091	64,302,386	110	7073	42,440	24,113	18,503	16,068
2022	13,022,375	77,324,761	110	8506	51,034	28,997	24,967	18,058
2023	14,139,262	91,464,023	110	10,061	60,366	34,299	32,063	19,962
2024	15,308,750	106,772,773	110	11,745	70,470	40,040	39,826	21,779

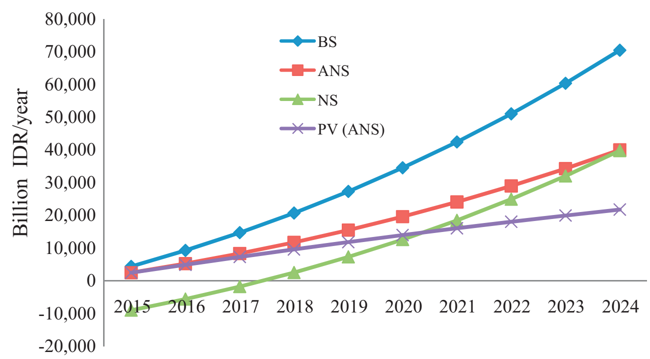

Fig. 5. Annualized result of economical impact of passenger cars fuel economy Labels (billion IDR/year).

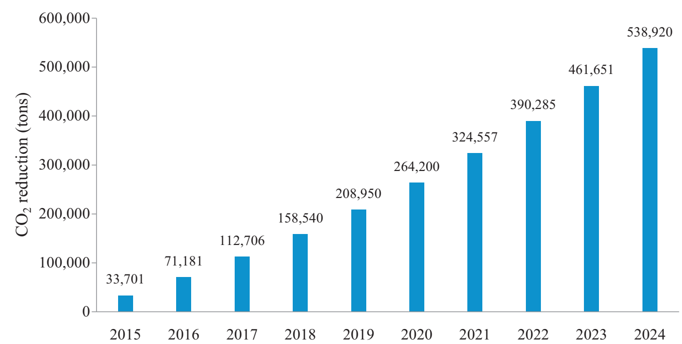

Fig. 6. Annualized CO_2 emissions reduction (tons) due to passenger cars fuel economy labels.

Table 6
Annual emissions reduction by introducing fuel economy labels between 2015 and 2024.

Year	CO_2 (tons)	HC (kg)	NO_x (kg)	CO (kg)
2015	33,701	753,291	624,626	1,597,847
2016	71,181	1,591,045	1,319,288	3,374,854
2017	112,706	2,519,197	2,088,908	5,343,611
2018	158,540	3,543,683	2,938,407	7,516,704
2019	208,950	4,670,435	3,872,706	9,906,721
2020	264,200	5,905,389	4,896,725	12,526,252
2021	324,557	7,254,479	6,015,385	15,387,882
2022	390,285	8,723,640	7,233,608	18,504,202
2023	461,651	10,318,806	8,556,313	21,887,798
2024	538,920	12,045,912	9,988,422	25,551,258

4.3. Economical impact

The economic impact consists of the potential bill savings, annual net savings, net savings and cumulative present value. The economic impact is actually a function of the energy savings and investment for more efficient appliances due to the labels. Using Eqs. (9)–(11), Table 3 and Fig. 4, the calculation results of bill savings, annual net savings, and cumulative present value are tabulated in Table 5 and illustrated in Fig. 5. The label program pursued from 2015 to 2024 will achieve bill saving of IDR 335,363 billion (USD 34,221 million), annualized net saving of IDR 190,548 billion (USD 19,444 million) and net saving of IDR 121,635 billion (USD12,412 million) respectively. All these results proved that introducing fuel efficiency labels for passenger cars offers great economical benefits for consumers in a developing country like Indonesia.

4.4. Environmental impact

The environmental impact of fuel economy labels is a function of fuel saving which is the potential reduction of emissions that cause negative impact to the environment. Using Eqs. (12), Table 3 and Fig. 4, the detailed results of emissions reduction between 2015 and 2024 are illustrated in Figs. 6 and 7 and Table 6 respectively. Total emission reductions for CO_2, HC, NO_x and CO are tabulated in Table 7. The accumulation of these emission reductions will help to reduce its negative impact on the environment.

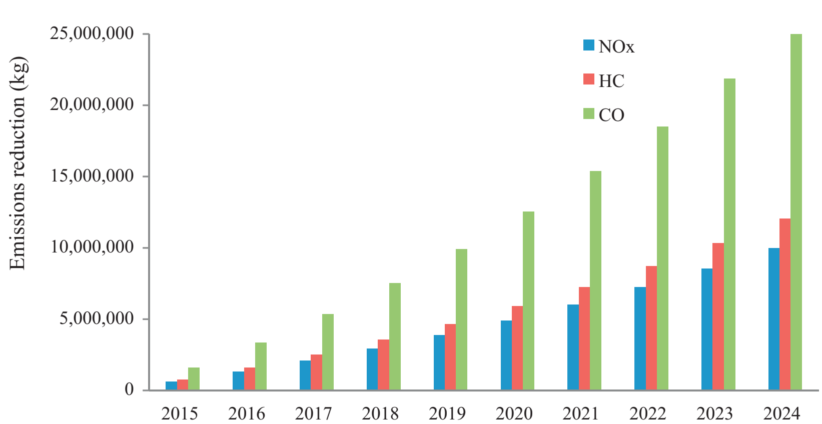

Fig. 7. Annualized NO_x, HC and CO emissions reduction due to passenger cars fuel economy label.

Table 7
Total emissions reduction by introducing fuel economy labels between 2015 and 2024.

Emission	CO_2 (tons)	HC (kg)	NO_x (kg)	CO (kg)
Total	2, 564, 691	57, 325, 878	47, 534, 389	121, 597, 129

5. Conclusions

The concept of fuel economy labels for passenger cars has been introduced globally. Labelling could play an important role in consumers' vehicle purchasing decisions between similar vehicles that have different fuel efficiency ratings. Currently, Indonesia does not have fuel economy labels. However, it is expected that fuel economy labels will be implemented in the near future due to the growth of passenger cars and the increasing demand for oil. It has been found that, a total amount of 55,894 million litre, IDR 335,363 billion (USD 34,221 million) and 2,564,691 tons of CO_2 could be saved between 2015 and 2024 due to implementation of fuel economy labels. This paper found that introducing fuel economy labels for passenger cars in Indonesia has proven its viability and offers huge fuel saving as well as economical and environment benefits.

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